supposition that the substance is throughout the period of heating coated with a film of water adiathermanous and the external surface of which may be considered as appreciably that of the steam. The danger then of radiation error, that is, of steam condensing elsewhere than at the surface of the substance, is small. Condensation, in short, may be considered as taking place by abstraction of the energy of the molecule on impact with the water film.

II. " On the Specific Heats of Minerals." By J. JOLY, B.E., Assistant to the Professor of Civil Engineering, Trinity College, Dublin. Communicated by Professor FITZGERALD, F.R.S. Received June 28, 1886.

A number of experiments were made on minerals by the method of condensation, using the form of gravimetric calorimeter described in the beginning of the paper on calorimetry (p. 353). The condensation of steam being in all cases employed, the values recorded are the mean specific heats between atmospheric temperatures approximating to 12° C., and steam temperature, about 100° C. More exactly, the values recorded are the mean calorific capacities for a rise of one degree between the limits t_1 and t_2, tabulated in each case. The specimens dealt with were chosen as good samples of the mineral free from visible impurities.* But before detailing the particulars of the experiments a few notes on the discriminative value and physical interest attached to this application of calorimetry may not be amiss.†

It seems probable that the neglect of the use of the specific heat constant is to be ascribed to the difficulties besetting its determination. Certainly if its determination was as easily effected as we effect the determination of the specific gravity of a body, there are on the other hand sufficient reasons to recommend its use as in general of more physical value and interest than the much used specific gravity. There are cases indeed where specific gravity, as it is possible to obtain it, is misleading, and where specific heat gives at once valuable information on the probable chemical nature of the substance. Such cases would arise with bodies of loose vesicular or hollow structure. No misleading variations need be introduced into the thermal constant by mere conditions of volume.

The method of condensation permits of the determination of this constant with very little experimental difficulty. On the whole the

* I have to thank Professor Sollas for the loan of useful specimens from the Museum of Trinity College.

† In November, 1883, I suggested this use of calorimetry to the Experimental Science Association, Trinity College.—" On the Determination of Minerals by their Specific Heats."

process is involved with no more liability to error than the process of weighing a body in air and in water.   If, however, accuracy —greater than 1 per cent.—be desired, the operation takes considerably more time, as it is necessary, in securing t_1 accurately, to leave thermometer and specimen a sufficient time together in the calorimeter.   The simplicity of the method is perhaps best inferred from the fact that of over 130 experiments on minerals there were but three spoiled—due to mishaps ; and it will be seen that the repetition experiments reveal in no case appreciable discrepancy.

That this specific heat constant is very sensitive to the presence of impurities or variations in the chemical nature of the substance cannot be considered a disadvantage.   It is supposable that this might lead occasionally to useful enquiry.   This sensitiveness is shown in the case of tourmaline.   Of three specimens the specific heats were—

> Hemihedral, *black* crystal . . . . $= 0\cdot2000$
> Striated, *black* crystal . . . . $= 0\cdot2008$
> Hemihedral, *brown* crystal . . . . $= 0\cdot2111$
> The same, a second experiment . . . . $= 0\cdot2112$

The variation from the black to the brown is over 5 per cent.   Now tourmaline experiences considerable variations in the two constituents iron and magnesium.   Approximately in percentage composition according to Dana's table of analyses—

	FeO.	Fe$_2$O$_3$.	MgO.
Black tourmaline contains	6	8	1
Brown tourmaline ,, ...	0	1	11

which in view of the high molecular heat of magnessia and the low molecular heats of the oxides of iron would account for the differences in the experiments.   It will be seen later in the particulars of these experiments that the densities of these crystals also, in a less degree, reveal the difference in composition.

Again attention is suggestively drawn by the thermal constant to the chemical compositions of the first two of these three aerolites from the Museum of Trinity College.

(1.) Fell in Co. Limerick, September 10th, 1813 . . . . . . $0\cdot1787$
(2.) Fell in Maryland, U.S.A., February 10th, 1825. . . . $0\cdot1785$
(3.) Fell in Spain, July 8th, 1811 . . . . $0\cdot1856$

The specific gravities, too, of the first couple, are found to be identical, thus : (1) $= 3\cdot604$; (2) $= 3\cdot601$; (3) $= 3\cdot435$.   The experiments, in fact, evidently afford strong reasons for believing that the first two aerolites constitute a case of the strange similarity alluded to by Daubrée :—" Il y a des météorites éloignées au double point de

vue géographique et chronologique qui présentent parfois l'identité la plus complète, de telle sorte qu'il est impossible d'en distinguer les échantillons respectifs."* He adds a list of the few such occurrences known.

It is an important feature that the value of the thermal constant admits of being approximately, sometimes closely, calculated on an assumed chemical composition, and thus can be used in identification where comparative data do not exist or are not at hand. This fact rests on the experimental basis that the specific heat of the atom is preserved nearly constant through various atomic groupings. This applies indeed, only so far as the specific heats of the elements have been determined in the solid state ; when the generalisation is applied to molecules containing elements whose specific heats as solids have never been directly determined it ceases to be accurate, and it appears at present as if in each kind of grouping a particular thermal capacity must be assigned to the atom. Approximate values of these thermal capacities have, however, been calculated by Kopp and others, and thus it is possible in all cases to pronounce for or against an hypothesis as to the nature of a substance, and this not alone in the case of simple salts, but when dealing with the silicates where many different kinds of atoms are present.

In the case of the bisilicate beryl, for example, the most probable formula is $5BeO,2Al_2O_3,H_2O,11SiO_2$.† Of these molecules the specific heat of BeO has alone not been directly determined. We take for the specific heat of Be $0·430$,‡ and taking the atomic heat of solid oxygen as $4·5$—the value it affords approximately in compounds having the constitution RO§—we assume its sp. h. in the molecule to be $0·281$. On these assumptions the sp. h. of BeO would be $0·335$. The atomic weight of Be is taken as $9·1$. Taking advantage, then, of direct determinations as far as possible, the data are, sp. h. of BeO $0·335$, of Al_2O_3 $0·198$,‖ of H_2O $0·501$,¶ of SiO_2, $0·188$.** From these, by an equation similar to Woestyn's—††

$$WS = n_1w_1s_1 + n_2w_2s_2 + \ldots,$$

where s_1, s_2, . . . are the specific heats of the several kinds of molecules as above ; n_1, w_1, n_2, w_2, . . . the numbers and atomic weight of

* 'Géologie Expérimentale, Constitution des Météorites,' p. 507.

† From Penfield's result that the composition is $Be_5,Al_4,Si_{11}O_{34}$, 'Nature,' vol. 30, 1884, p. 378. The ratio is not quite bisilicate. Mr. Penfield thinks, however, that water should be included in the formula.

‡ 11° to 100°, Humpidge, 'Roy. Soc. Proc.,' vol. 39, 1886, p. 8.

§ Kopp.

‖ From my own results on corundum, agreeing with Regnault's.

¶ Person's result on ice, −20° to 0°. Landolt and Börnstein's 'Tabellen.'

** My own result on quartz, agreeing with Neumann's.

†† 'Annales de Chimie,' vol. 23, 1848, p. 295.

each kind of molecule present in the substance; W the molecular weight of the entire compound $= \Sigma \, wn$; s the required specific heat —the sp. h. of beryl is found to be 0·2140. The experimental results are

α. Transparent crystals .... 0·2066
β. Clouded crystals................ 0·2126

With the last variety the agreement is very close, but in either case the agreement is sufficient to render the calculation strong evidence had the case been one of hypothesis as to the nature of the substance.

I proceed to quote a case where the identification of a mineral was in this way left to the calorimeter.

The mineral had been assigned a place in a small collection as cryolite, on supposition. Its sp. h. was found to be 0·2558. This at once distinguished it from gypsum—sp. h. = 0·278—which it resembled in appearance. As I knew of no experiments on cryolite it was necessary to calculate the constant. The formula of cryolite— $3NaF + Al_2F_3$—includes the sp. hs. of Na, F, and Al. Of these F has not been directly determined. Its probable value was deduced from the sp. h. of fluorspar, which I had found to be 0·2118. Ascribing to the calcium in this compound the value 0·170 (Bunsen), the sp. h. of fluorine is deduced as 0·251, which agrees with Kopp's result. The other atoms in cryolite were assumed as follows: to the sodium was assigned Regnault's value 0·293, to the aluminium that obtained by myself, 0·223. On these assumptions the calculated sp. h. of cryolite is 0·2569. The experiment on the hypothetical cryolite affording 0·2558, the diagnosis was assured. A test of fusibility now confirmed the result, and subsequently an authentic specimen of cryolite gave 0·2538.

The calculation may also be effected on the percentage composition. It is a readier method but, it is remarkable, not so agreeable with the practical result. Thus in the case of cryolite, $Al = 13·21$, $F = 53·56$, $Na = 32·65$ in the mean analysis (Dana), and by the equation

$$S \times 100 = w_1 s_1 + w_2 s_2,$$

where w_1, w_2, . . . are the percentages, s_1, s_2, . . . the sp. hs. of the constituents, the result is $S = 0·2591$.

The specific heats of a few substances occasionally confounded are gathered here.

$\begin{cases} \textit{Apatite,} \text{ opaque } .... & 0·1920 \\ \quad ,, \quad \text{ translucent.............} & 0·1829 \\ \textit{Beryl,} \text{ clouded ....} & 0·2127 \\ \quad ,, \quad \text{ transparent..............} & 0·2066 \end{cases}$

Orthoclase, transparent	0·1869
„ opaque	0·1890
Labradorite	0·1933
Oligoclase, transparent	0·2059
„ sub-translucent	0·1997
Albite	0·1983
Microcline....................	0·1905
Tourmaline, black	0·2004
„ brown..............	0·2111
Epidote, dark-green	0·1877
Hypersthene, dark-brown	0·1790
Amphibole, black	0·1963
Quartz	0·1881
Topaz	0·1997

Many of these substances may, of course, be also distinguished by
their specific gravities. There is indeed, as might be expected, a
connexion apparent between the two, the quantities tending to vary
inversely, not only from one substance to another, but in the case of
variations in specimens of the same species.

In its physical interest I think calorimetry deserves the attention of
mineralogists. From results which came under notice in the course
of the experiments on mineral crystals, I think it will be allowed that
questions of interest are raised. These observations are in one direc-
tion only, and I have not had leisure to pursue them with the thorough-
ness they appear to me to deserve. Many questions suggest themselves
on molecular freedom within the crystal which will need care and
preparation to answer, and I now but give in outline an account of
observations made, I may say, incidentally.

The crystallographic interest of the thermal capacity is based upon
what is apparently an intimate connexion with the amount and kind
of freedom possessed by the atoms of the solid. This is perhaps
hardly unexpected. It is probable that calorific capacity, tending to
be reciprocal to the mass of the atom, is more concerned with the
intrinsic nature of the atom than with its surroundings. Still on any
hypothesis of a vibratory molecule it is easy to conceive that if the
surroundings are such as to hamper its freedom of motion the constraint
will be revealed in its specific heat; that is, if we assume its increase
of energy to be kinetic, as in increased amplitude of vibration. It
might be expected then that in the crystal the atom would reveal
thermally greater freedom than in the amorphous state. If, in fact
crystalline arrangement be regarded as the result of harmony among
molecular vibrations, we would expect for the crystal a specific heat
approximating to that of the free molecule, and the more nearly
approaching it the more perfectly harmony prevailed in the crystal.*

* There are not many experimental data for comparing the specific heat of the

It is here assumed that in some way similar to that in which the atom passes into the compound molecule without, in general, sensible change of thermal capacity, the molecule passes into the crystal with only insignificant further change in thermal capacity; the crystal being regarded in some sense as the chemical combination of the molecule. Thus we expect the specific heat of the crystal to be lower than that of an amorphous aggregation of its atoms under the constraint of discord. This agrees with experiment, for it may be stated as true generally that in the crystal the specific heat is lower than in the amorphous state, and that the more perfect and complete the state of crystallisation the lower the observed specific heat.

This, the first fact brought to my notice as experiments multiplied, seems to hold through the nicest indications of crystalline state as facial lustre, degree of translucency, as well as through the more marked indications of cleavage and form, and is probably quite in accord with the well-known fact that rolling, hammering, and such operations as tend to increase the density, diminish the specific heat of metals. The same would, doubtless, be found to hold in the case of the crystalline polarity conferred on metals by vibration.

I might illustrate the fact by a considerable number of cases where it happened that the specimens dealt with showed differences in crystalline state. I will only quote a few, referring to the tables for other cases. It is apparent in the case of *Barite* :—

Limpid crystal................	0·1092
Sub-transparent crystal........	0·1105
Opaque, lamellar..............	0·1116

In the case of *Gypsum* :—

Transparent..................	0·2726
Opaque, rough................	0·2737

Sphalerite :—

Crystal, high lustre............	0·1144
Crystalline, divergent..........	0·1155
„ massive............	0·1162

Orthoclase :—

Limpid......................	0·1869
Opaque, well-formed crystals ..	0·1886
Massive, cleavable............	0·1899

Fluorspar, cryolite, calcite, and quartz-opal are also examples. The case of opal is, however, uncertain, owing to probable presence of

molecule in crystalline freedom with the specific heat of the molecule in gaseous freedom. In the case of ice and steam. they are the same nearly ; (Regnault) ice (−78° to 0°) = 0·474; steam (128° to 220°) = 0·480°.

water. I came on no exceptions. There is, indeed, a more con-
spicuous kind of variation shown in the specific heats of minerals not
always determinable by external appearances, but this cannot, I think,
be classed with the foregoing. It is, however, difficult at present to
draw the line between them. But so far it seems highly probable that
in slight differences of thermal capacity may be recognised a mole-
cular restraint or discord or whatever molecular condition results in
opacity, roughness, incompleteness, formlessness.

That other kind of variation to which I allude is of a different
order of magnitude, and, I venture to suggest, points to causes of
different order. It suggests the possibility that more than one
molecular arrangement may obtain in bodies chemically and crystallo-
graphically, to all appearance, identical. For example, in hexagonal
prisms of beryl two very different degrees of molecular freedom would
appear to be possible. Certainly two very different thermal capacities
obtain, unexplained by chemical differences or crystallographic form,
so far as I can ascertain. The variation, too, seems in no way con-
nected with the density of the substance, for this may be invariable
from one specimen to another, while the difference of specific heat is
remarkable. In many cases this difference of structure, if such it be,
is revealed in the behaviour of the substance to light, in the opacity
or transparency of the crystal. So marked is this that specific heats
may be at once assigned with certainty to different crystals of known
minerals on their opacity or transparency. In some cases again the
substances present no differences whatever in appearance. The case
of beryl stands thus :—

		Sp. h.	Sp. gr.
	Transparent, blue, six small crystals....	0·20587	2·676
α	,, blue crystal	0·20705	2·666
	,, greenish crystal	0·20636	2·660
	Sub-translucent, green crystal	0·21257	2·706
β	,, ,, ,, ...	0·21236	2·706
	Opaque, dull-greenish crystal..........	0·21306	2·644

Between the α and β specimens above there is no difference
apparent in crystallographic development save in the case of a couple
of the small α crystals of the first experiment, which show pyramidal
as well as the basal and prismatic faces common to all the specimens.
Examination of the twenty analyses collected by Dana ('Mineralogy')
suggests no explanation on chemical grounds. The percentages
throughout vary in no adequate degree, ascribing to the molecules the
thermal values recorded previously in arriving at a result by calcula-
tion agreeing with the β specific heat. I do not think, too, that
results independent, as they constantly seem, of density can with
probability be ascribed to differences in the amounts of the constituent

atoms.   There is more probably some difference in constraint, of a structural kind, affecting the freedom of the molecules.   Des Cloizeaux is of opinion that the optical examination of emerald, "and above all of beryl," points to a biaxial constitution.*   In recently noting on these same clouded green β-beryls from our Dublin granite, I had occasion to remark on their optical heterogeneousness.†   The extinction of basal sections is not uniform between crossed Nicols ; pale grey cross-hatching is apparent, and as the mineral is rotated extinguishes capriciously over the field.   In these patches the restoration of illumination is feeble and suggests imperfect coincidence of optic and crystallographic axes.

A still greater variation appears in the sp. h. of corundum from the clouded to the limpid variety, basing the sp. h. of the latter on Regnault's result on sapphire.   It is remarkable, however, that the variation is in the opposite direction—the limpid variety exhibits the higher, the clouded the lower sp. h.   Thus :—

a { Corundum.................   0·197.   R.
{ Clouded crystal of corundum..   0·198.   J.
β Sapphire ....   0·217.   R.

This is a variation of 10 per cent. about.   Now the analyses given in Dana's 'Mineralogy' of sapphire and corundum, although variable and pointing sometimes perhaps in the direction of the calorimetric result, certainly warrant no such difference, while on the other hand the sp. gr. of the two varieties are invariably opposed to the result being lower in the common variety than in the gem.   It is perhaps remarkable that both these minerals, beryl and corundum, are hexagonal.   A third case occurs in the case of calcite.   I experimented on Iceland spar and on a clouded milk-white rhombohedron, and also on a specimen consisting of an aggregation of dihexagonal prisms.   Adding the observations of others an a and β variety of calcite is suggested.

	Sp. h.	Sp. gr.	Observer.
a { Iceland spar.................	0·2036	2·713	J.
{ Clouded rhombohedron	0·2044	2·702	J.
{ Iceland spar.................	0·2046	—	N.
β { Translucent di-hexagonal prisms	0·2091	2·658	J.
{ Iceland spar, two specimens	0·2086	—	R.

In addition there is an observation of Kopp's 0·206; it is highly probable, however, from a consideration of Kopp's general results, his method of working, and, indeed, his own acknowledgement, that this is too low.   It is likely he was dealing with β-calcite.   It is to be remembered that Iceland spar is chemically a very pure form of the mineral.

* 'Minéralogie,' vol. 1, p. 366.
† [1885] 'Roy. Dublin Soc. Proc.,' vol. 5, p. 49.

The case of aragonite is unexpected. Its specific heat has been obtained by Regnault, Kopp, Neumann, and myself. The experiments fall into α- and β-groups, having values identical with those of calcite, and the remarkable fact appears that although the minerals differ in crystalline symmetry and specific gravity, the evidence is in favour of ascribing the same thermal capacities to both. The experiments are—

				Sp. h.	Sp. gr.	Observer.
α	Two transparent crystals (Bohemia)			0·2040	2·955	J.
	,, ,, ,,	(Auvergne)		0·2039	2·955	J.
	Aragonite			0·2030	—	K.
β	,,			0·2085	—	R.

Neumann's result, 0·2018, probably comes under the α variety. A coincidence of error adequate to account for this nearly unanimous agreement between the two forms of calcite is improbable. The inference would appear to be that in both forms the molecules possess nearly equal freedom. From my own results on transparent crystals of both forms the molecular restraint seems perhaps greater in aragonite. This is probable, too, from the phenomena attending the heating of aragonite. The crystals spontaneously break and develope cracks even at the low temperature of the steam ; a phenomenon which, be it observed, probably in some slight degree falsifies the results.

The sp. h. of a specimen of massive rough barites from Glendalough, co. Wicklow, is sufficiently remarkable to justify notice. In this case the nearly pure nature of the specimen was placed beyond doubt by analysis. The sp. h. obtained was—

	Sp. h.	Sp. gr.
Rough crystalline barites	0·10316	4·172

my other observations on this mineral ranging from 0·1092 to 0·1117. Neumann records 0·1088 ; Regnault, 0·1128. As the specimen was unaffected by acids, the presence of $PbSO_4$ was suggested as the only likely admixture competent to lower the sp. h. On this account I analysed the substance. The result is—

$BaSO_4$	99·1
MnO_2	0·3
$CuFeS_2$	0·2
Pb	trace
Ca	trace
Fe_2O_3	0·6
	100·2

The specific gravity, it will be seen, is also abnormal for barites (4·3—4·7, Dana). The sp. gr. of the other specimens examined by

me approximate to 4·4. It is certain that the small quantities of impurities present, acting merely by their atomic heats, would not suffice appreciably to alter the sp. h., and would rather tend to elevate it.

To these cases may, perhaps, be added those of apatite and oligoclase. I examined but two specimens of each.

Apatite.

	Sp. h.	Sp. gr.
Translucent hexagonal prism, high lustre, brittle	0·1826	3·166
Opaque, dull compact crystal	0·1920	3·089

Oligoclase.

	Sp. h.	Sp. gr.
Sub-translucent, milk-white (Ytterby)	0·1997	2·621
Transparent crystal	0·2059	2·605

It remains to notice the cases of three chemically and crystallographically related minerals where the variations obtaining in each case would appear to stand in a numerical relation from one substance to another. The minerals are iron pyrites (isometric disulphide of iron); galenite (isometric sulphide of lead); sphalerite (isometric sulphide of zinc). The orthorhombic disulphide of iron, marcasite, seems also to fall into the relationship.

The specific heat of pyrites is, according to Regnault, 0·13009. Operating on a large bright cube, I obtained the same number exactly, 0·13009. Neumann's result is 0·127, Kopp's 0·126. The specific heat of galena is given differently by Regnault, Kopp, and Neumann. The value given by Kopp, 0·0490, closely agrees with an observation of my own, 0·0492. I also obtained 0·0504 and 0·0522 on well crystallised specimens. The last number is probably a little excessive, as there was just a trace of a white substance—the carbonate—present. There are found finally for pyrites and galena the numbers—

Pyrites.

N......	0·127	....	R......	0·130
K......	0·126	....	J......	0·130

Galena.

K....	0·0490	R....	0·0508	J....	0·0522	N....	0·053
J....	0·0492	J....	0·0504				

Taking the means of the first two vertical colums in each case, the proportion holds very closely

<div align="center">

Pyrites.   Galena.

126·5 : 130 :: 491 : 506.

</div>

The experiments are so close that any of the recorded values are fairly in the proportion, and some evidently better than the means; thus if my own results and Neumann's be alone considered, it will be found that the ratio is almost absolute.   As it stands, on the mean values, the products are as 638 to 640.

If Neumann's result for marcasite, 0·133, be included, we find the more extended proportion—

<div align="center">

Pyrites.   Galena.

126·5 : 130 : 133 :: 491 : 506 : 522.

</div>

But in this the last number is a little excessive, which, as observed, is probably due to impurity.

Two distinct values, very different, are on record for *sphalerite :*—

N......	0·114	......	R......	0·123
J......	0·115	......	K......	0·120

and finally the proportion with the extreme values of pyrites and galena obtains.

<div align="center">

Sphalerite.   Pyrites.   Galena.

114·5 : 121·5 :: 126·5 : 133 :: 491 : 522.

</div>

If this proportion be examined by products of consequent and antecedent of first term with sum of antecedents and consequents, the products obtained are as 88,938 to 88,909.   One value only, it will be seen, is omitted from the ratios, that of Neumann, for galena.   It appears to lie outside the proportion, and may either be erroneous or simply indicative of corresponding terms not yet found for the other sulphides.

In conclusion, I would ask in reference to the foregoing remarks, if in the present state of our knowledge there is anything *à priori* improbable in different molecular arrangements or orientations obtaining under the same crystalline form and affecting to definite extents the thermal freedom of the molecule.   Such differences of arrangement, hardly detectable perhaps by any other means of investigation, might exist unnoticed except when, as possibly occurs in the case of marcasite, prevailing to a degree competent to determine a different symmetry for the aggregate.

Regarding the experiments which follow, I have only now to observe on the precautions observed in effecting them.

The thermometers, certified at Kew, read directly to 0·1° C.; the place of hundredths being obtained by estimation.

The balance used was trustworthy to 0·0005 gram.   To secure t_1 accurately indicating the temperature of the substance, thermometer and specimen were left together in the calorimeter—starting at air temperature—never less than one and a half hour; large specimens,

two to three hours; and the largest were reserved for leaving in all night.

Specimens presenting at all a porous or loose surface were carefully dried, often for many days, in an oven, and subsequently preserved over calcium chloride. Porous or loose substances, not of special value, were, for greater surety in drying, broken into small bits— as in the case of the few rock specimens investigated. To preserve these dry in the calorimeter, while acquiring air temperature, calcium chloride was in some cases placed in the little chamber projecting from the lower part of the sphere. If counterpoised immediately on being placed in the calorimeter absorption of moisture may evidently be detected, weighed, and its thermal capacity allowed for. This plan was on a couple of occasions resorted to. In any cases observed, however, entire neglect of this absorption would have produced but small error.

Supposing errors of the same sign to accumulate through an experiment, I do not think they can have in any case falsified the value of the sp. h. above 0·4 per cent. This seems probable, too, from the agreement observed on repetition.

Allowance has in all cases been made for the variation of λ with t_2, according to Appendix of last paper. The effect of the low specific gravity of steam on the apparent weight of condensation has been allowed for, as— $\dfrac{W}{Sp.\ gr.} \times 0\cdot 62$ gram. With these deductions and allowance for the precipitation on the carrier and bucket according to range of temperature obtaining, the value of w is deduced as recorded in the tables.

The specific gravities recorded have been reduced to water at 4° C.

Specific Heats of some Minerals.

	W.	t_1.	t_2.	w.	Sp. h.	Sp. gr.
Galenite, PbS. Isometric:—						
Four well-formed crystals—cubo-octahedral	62·964	13·27	99·50	0·5105	0·05406	7·323
Close grained fragments	87·840	13·27	99·60	0·6955	0·04921	7·562
Very cleavable fragments	56·967	10·50	99·90	0·496	0·05224	7·365
Another experiment	56·951	10·98	99·76	0·493	0·05232	„
„ „	56·951	11·77	99·70	0·487	0·05219	„
Other observers...... R.=0·05086; N.=0·053; K.=0·0490.						
Sphalerite, ZnS. Isometric:—						
Cleavable, high resinous lustre, dark brown	45·765	11·80	100·18	0·863	0·11445	4·082
Fibrous, divergent, dark brown	80·520	11·40	100·30	1·610	0·11553	4·039
Compact, crystalline, dark brown	31·893	9·90	99·90	0·622	0·11625	4·020
Other observers...... R.=0·1230; N.=0·1145; K.=0·120.						
Pyrite, FeS$_2$. Isometric:—						
Large bright cube	55·890	12·23	99·70	1·1785	0·13009	4·938
Cubes stained with limonite	73·809	12·40	99·40	1·597	0·13443	4·832
Cubes and pyritohedrons, bright	57·671	12·30	99·70	1·2265	0·13059	4·808
Two interpenetrated cubes, bright, pale	46·710	10·50	99·90	1·016	0·13111	4·854
Other observers...... R.=0·13009; N.=0·1275; K.=0·126.						
Chalcopyrite, CuFeS$_2$. Dimetric:—						
Crystalline fragment, bright, iridescent	48·687	11·40	100·00	1·0225	0·12717	4·143
Another experiment	48·645	12·55	99·90	1·0065	0·12708	„

Specific Heats of some Minerals—*continued.*

	W.	t_1	t_2	$w.$	Sp. h.	Sp. gr.
Fluorite, CaF. Isometric:—						
Clear green cube	32·957	10·40	100·00	1·166	0·21180	3·172
Crystalline, translucent, green............	31·275	9·75	100·10	1·117	0·21264	3·171
Other observers...... R.=0·2149; N.=0·2082; K.=0·209.						
Cryolite, $3NaF + Al_2F_3$. Trimetric (?):—						
White, subtransparent	58·438	13·00	100·25	2·480	0·25385	2·963
,, translucent	43·060	11·50	99·70	1·8105	0·25583	2·961
Other observers......... K.=0·238.						
Corundum, Al_2O_3. Hexagonal:—						
Hexagonal prism, clouded, pale blue	102·820	12·56	99·90	3·314	0·19800	3·963
Another experiment	102·820	12·62	99·80	3·3135	0·19820	,,
Other observers...... R.=0·19762, and sapphire 0·21732.						
Hematite, F_2O_3, Rhombohedral:—						
Botryoidal, divergent	61·175	13·50	99·80	1·6495	0·16766	4·644
,, ,, ...	67·604	7·80	100·40	1·976	0·16893	4·923
Other observers......Specular iron, R.=0·1670; N.=0·1692; K.=0·154.						
Limonite, $F_2O_3 + 3H_2O$:—						
Divergent, brown, silky.................	58·990	13·27	99·78	2·107	0·22632	4·037
Pseudomorphous after pyrites, brown ...	26·492	13·63	99·65	0·961	0·22155	3·886

Specific Heats of some Minerals—*continued.*

	W.	t_1.	t_2.	w.	Sp. h.	Sp. gr.
Quartz, SiO_2. Rhombohedral :—						
Ten small crystals, limpid, R, ∞, -1	32·921	11·95	99·75	1·0125	0·18800	2·649
Smoky crystal, trapezohedral (left, tetartohedral) with R, ∞, -1 ..	29·743	13·10	99·60	0·9025	0·18828	2·649
Clear limpid, R, ∞, -1	17·572	11·83	99·30	0·539	0·18827	2·652
Clear, R, ∞, -1	14·686	16·50	100·22	0·4305	0·18780	2·649

Other observers......R.=0·1913; N.=0·1883; K.=0·186.

	W.	t_1.	t_2.	w.	Sp. h.	Sp. gr.
Opal, SiO_2. Amorphous :—						
Hyalite, limpid, spheroid aggregations	28·468	13·25	99·60	0·931	0·20330	2·168
White, nearly opaque	22·456	8·20	99·90	0·913	0·23785	2·106
Another experiment	22·437	13·20	99·40	0·855	0·23733	,,

Other observers......K.=0·197 (Hyalite); K.=0·208 (noble opal).

	W.	t_1.	t_2.	w.	Sp. h.	Sp. gr.
Hypersthene, $(MgO,FeO)SiO_2$. Trimetric :—						
Crystalline, massive, dark brown....	69·398	13·55	100·08	2·0045	0·17900	3·819
Another experiment	69·336	13·25	99·80	2·001	0·17891	,,

	W.	t_1.	t_2.	w.	Sp. h.	Sp. gr.
Amphibole, Bisilicate of Protox. and Sesquiox. bases. Monoclinic :—						
Five black crystals, O.I. $\tilde{v}$, -1	57·192	12·00	99·72	1·8355	0·19634	3·183
Two largest of the five....	45·133	12·94	100·30	1·4435	0·19635	,,
Three largest of the five	51·309	12·90	100·30	1·6405	0·19619	,,

Probably aluminous magnesia-lime-iron hornblende.

Specific Heats of some Minerals—*continued.*

	W.	t_1.	t_2.	w.	Sp. h.	Sp. gr.
Beryl, $3BeO + Al_2O_3 + 6SiO_2$. Hexagonal:—						
Six small crystals of clear blue aquamarine	26·050	12·47	99·10	0·865	0·20587	2·676
Transparent blue aquamarine	13·966	11·72	99·91	0·475	0·20707	2·666
Another experiment	13·938	9·75	100·00	0·4885	0·20703	„
Transparent pale green	47·336	12·40	99·80	1·591	0·20636	2·660
Clouded green, well crystallised, high lustre	37·495	6·80	100·10	1·371	0·21257	2·706
Clouded green prism (Glencullen, Co. Dublin)	49·502	11·90	99·45	1·7145	0·21236	2·708
Clouded greenish-white, radiating (Glencullen)	13·016	16·69	100·07	0·431	0·21306	2·644
Garnet, $\ddot{R}_6 \bar{\ddot{R}}_2 \ddot{S}i_6$. Isometric:—						
Two dark red crystals	50·940	10·65	99·90	1·5095	0·17813	3·978
Another experiment	50·940	12·65	99·90	1·474	0·17792	„
Dark red crystal	39·094	12·30	99·90	1·145	0·17934	3·757
Another experiment	39·094	12·60	99·90	1·141	0·17929	„
Principal bases probably Al_2O_3 and FeO.						
Vesuvianite, $(\frac{3}{2}\dot{C}a_3 + \frac{2}{5}\bar{\ddot{A}l})_2 \ddot{S}i_3$. Dimetric:—						
Two translucent dark green crystals, high lustre	24·879	12·53	99·78	0·790	0·19529	3·353
Another experiment	24·879	12·00	100·30	0·797	0·19457	„
Epidote, $\dot{C}a_6(\bar{\ddot{A}l}, \bar{\ddot{F}e})\ddot{S}i_9$. Monoclinic:—						
Two crystals, fine lustre, black-green	21·300	13·50	99·45	0·639	0·18740	3·430
Another experiment	21·300	13·45	100·30	0·649	0·18792	„

Specific Heats of some Minerals—*continued*.

	W.	t_1.	t_2.	w.	Sp. h.	Sp. gr.
Biotite, Magnesia-iron Mica:—						
Black, opaque flakes (Perth, Canada)	20·291	12·63	100·30	0·685	0·20651	2·841
Another sample of same	17·809	12·70	99·95	0·5935	0·20491	,,
Muscovite, Potash Mica:—						
Silvery-white crystals (Beleek, Co. Fermanagh) ...	23·735	13·80	99·75	0·778	0·20519	2·725
Another sample of same in flakes	20·541	12·40	99·90	0·6875	0·20466	,,
Lepidolite, Potash, Lithia Mica:—						
Massive, scaly-granular, fine lilac	42·726	12·20	100·20	1·4705	0·20978	2·833
Another sample of same	48·823	12·38	100·20	1·6760	0·20967	,,
Wernerite, $\mathrm{\dot{C}a_3\ddot{Al}_2\ddot{Si}_6}$. Dimetric:—						
Two interpenetrating prisms, opaque, rough, grey.	34·156	10·55	100·00	1·141	0·20036	2·590
Another experiment	34·156	12·10	100·30	1·125	0·20029	,,
Leucite, $KO,Al_2O_3,4SiO_2$. Isometric:—						
Two trapezohedral crystals, grey	15·937	12·00	99·95	0·4995	0·19119	2·454
Another experiment	15·937	12·84	99·90	0·496	0·19178	,,

Specific Heats of some Minerals—*continued.*

	W.	t_1.	t_2.	w.	Sp. h.	Sp. gr.
Labradorite, Lime-soda felspar. Triclinic:—						
Chatoyant polished specimen	44·155	13·50	99·72	1·3705	0·19320	2·691
Another experiment	44·155	12·29	100·05	1·3975	0·19348	,,
Rough, chatoyant (Labrador)	39·790	12·25	100·20	1·2625	0·19351	2·693
A similar specimen ,,	43·946	12·60	100·18	1·386	0·19317	2·692
Oligoclase, Soda-lime felspar. Triclinic:—						
Subtransparent crystal	39·534	12·00	99·45	1·3255	0·20580	2·605
Another experiment	39·534	12·20	100·05	1·3335	0·20600	,,
Milk-white, subtranslucent (Ytterby)	48·074	12·60	99·10	1·5465	0·19974	2·621
Another sample of same	41·829	11·60	99·40	1·366	0·19967	,,
Albite, Soda felspar. Triclinic:—						
Group of limpid twinned crystals, composition on *ī* (Tyrol)	23·991	12·50	100·20	0·8395	0·19846	2·630
Another experiment	23·979	12·63	100·18	0·7765	0·19840	,,
,, ,,	23·978	12·71	100·19	0·7753	0·19828	,,
Other observers..... K.=0·190.						
Orthoclase, Potash felspar. Monoclinic:—						
Transparent adularia	69·893	10·88	100·20	2·175	0·18688	2·561
Another experiment	69·887	13·20	99·76	2·108	0·18702	,,
Green-blue amazon stone, clearable	66·632	13·10	99·90	2·0155	0·18696	2·565
Two crystals, a Carlsbad and a Baveno twin, opaque white	23·359	14·37	99·35	0·6975	0·18865	2·445
White, nearly opaque, cleavable (Co. Dublin)	27·490	11·03	99·80	0·8585	0·18877	2·551
Red, very cleavable, subtranslucent (Castlecaldwell)	48·279	11·80	99·50	1·502	0·18992	2·546
Other observers...... N.=0·1861 (adularia); 0·1911 (orthoclase); K.=0·183 (orthoclase).						

Specific Heats of some Minerals—*continued.*

	W.	t_1.	t_2.	w.	Sp. h.	Sp. gr.
Microcline, Potash felspar. Triclinic:—						
Well-marked pink, cleavable (Glencullen, Co. Dublin)	30·863	13·45	99·10	0·931	0·18916	2·471
Another specimen from same locality	35·519	14·84	99·35	1·0745	0·19219	2·471
Large crystal, pink (Glenmalure, Co. Wicklow)	71·588	12·90	99·95	2·242	0·19302	2·531
Fawn-coloured, cleavable (Arendal)	33·124	12·37	100·19	1·031	0·19015	2·565
Another sample of same	29·052	12·50	100·20	0·9065	0·19084	2·559
Tourmaline, Subsilicate of MgO,BO_3,Al_2O_3,Fe_2O_3. Rhombohedral:—						
Hemihedral crystal, fine black lustre	30·588	11·78	99·50	1·0025	0·20005	3·139
Striated crystal ,, ,,	24·919	9·08	100·10	0·846	0·20082	3·104
Hemihedral brown crystals, translucent, little Muscovite present	24·747	12·90	99·50	0·8425	0·21114	3·010
A second experiment	24·747	12·57	100·00	0·842	0·21126	,,
The black is probably iron tourmaline ; the brown magnesian.						
Topaz, $Al_2O_3\{\frac{1}{2}SiO_2 + \frac{1}{2}SiF_2\}$. Trimetric:—						
Limpid fragment	37·571	10·60	99·70	1·2445	0·19989	3·568
A second experiment	37·571	15·40	99·80	1·179	0·19965	,,
Colourless, hemihedral	18·852	11·38	99·75	0·621	0·19953	3·541
Prehnite, $\dot{C}a_2,\ddot{A}l,\ddot{S}i_3 + \ddot{H}$. Trimetric:—						
Globular crystalline surface, translucent, green (Dumbartonshire)	39·105	12·12	99·45	1·276	0·20057	2·908
Another experiment	39·096	11·90	100·00	1·2845	0·20008	,,

Specific Heats of some Minerals—*continued.*

	W.	t_1	t_2	w.	Sp. h.	Sp. gr.
Natrolite, $Na_4AlO_{10}Si_3 + 2H_2O$. Trimetric:—						
Radiating group of white translucent crystals (Auvergne)	13·660	11·70	99·90	0·532	0·23689	2·244
Another similar specimen (Auvergne)	24·762	12·67	99·90	0·959	0·23819	2·243
Stilbite, $CaAl-O_{16}Si_6 + 6H_2O$. Trimetric:—						
Pearl-white radiating (Ireland)	28·583	11·25	99·40	1·230	0·26207	2·158
Dried at 100° (about) for some days before experiment.						
Talc, $6MgO,5SiO_2 + 2H_2O$. Trimetric:—						
Pale green soapstone	47·445	12·32	100·25	1·6855	0·21671	2·769
From same hand-specimen	44·631	13·30	100·20	1·568	0·21686	„
Serpentine, $3MgO,2SiO_2 + 2H_2O$. Trimetric (?):—						
Green, translucent (Galway)	31·014	11·20	99·80	1·295	0·25288	2·549
Apatite, $3CaOPO_5 + \frac{1}{3}Ca(ClF)$. Hexagonal:—						
Green-brown prism, high lustre, subtranslucent, brittle	76·287	11·20	99·90	2·3035	0·18263	3·166
Another experiment	76·290	12·08	100·30	2·300	0·18327	„
Opaque pink-white prism, dull surface (Krageröe)	22·870	12·45	99·73	0·714	0·19196	3·089
A second experiment	22·870	12·10	100·10	0·721	0·19217	„

Specific Heats of some Minerals—*continued.*

	W.	t_1.	t_2.	w.	Sp. h.	Sp. gr.
Barite, BaSO₄. Trimetric:—						
Limpid crystal. O.I.ii and brachydome; striæ on O	76·109	9·65	100·30	1·405	0·10923	4·475
Same in small pieces	65·143	9·60	99·80	1·195	0·10910	,,
Yellow crystal, subtransparent	20·717	12·83	99·23	0·3685	0·11054	4·474
Opaque white, lamellar	48·103	12·60	99·20	0·8665	0·11169	4·324
,, ,, rough*	49·863	9·80	100·40	0·869	0·10316	4·172
Other observers...... R.=0·1128; N.=0·1088; K.=0·108.						
Gypsum, CaSO₄+2H₂O. Monoclinic:—						
Transparent crystal of selenite	21·048	10·00	100·10	0·965	0·27264	2·311
Four transparent crystals of selenite	13·204	7·24	100·40	0·623	0·27164	2·313
Aggregate of acicular crystals	30·150	9·20	100·40	1·393	0·27167	2·399
Rough gypsum, white	31·547	9·98	100·40	1·456	0·27374	2·310
Other observers...... N.=0·2728; K.=0·259.						
Calcite, CaCO₃. Rhombohedral:—						
Limpid Iceland spar	33·904	10·00	99·76	1·156	0·20383	2·713
Same crystal in fragments	33·059	13·34	99·50	1·0795	0·20345	,,
Three slender hexagonal prisms, limpid	10·044	13·04	99·60	0·3295	0·20340	2·710
Translucent white rhombohedron	35·815	16·75	99·93	1·135	0·20439	2·702
Group of tapering prisms, some dihexagonal, translucent	31·524	11·90	99·50	1·0755	0·20908	2·658
Chalk, white (Newhaven) well dried	22·454	12·30	99·80	0·7475	0·20415	—
Another specimen of same	21·737	13·77	99·35	0·7065	0·20390	—
This chalk dissolves in HCl with very little residue. Heat of humectation may lower result.						
Other observers...... R.=0·2086 (Iceland spar); N.=0·2046; K.=0·206.						

* For analysis, see *ante*, p. 255.

Specific Heats of some Minerals—*continued.*

	W.	t_1	t_2	w.	Sp. h.	Sp. gr.
Aragonite, $CaCO_3$. Trimetric :—						
Two transparent prisms, yellow (Bohemia)	24·331	12·45	99·65	0·8065	0·20401	2·955
,, ,, colourless (Auvergne)............	28·161	11·60	99·00	0·9345	0·20393	2·955
Other observers...... R.=0·2085 ; N.=0·2018 ; K.=0·203.						
Witherite, $BaCO_3$. Trimetric :—						
Translucent crystal, white	41·407	13·68	99·25	0·716	0·10850	4·288
,, ,, ,, ...	64·172	12·90	99·75	1·130	0·10881	4·284
Other observers...... R.=0·1104 ; N.=0·1078.						
Malachite, $CuCO_3 + CuOH_2O$. Monoclinic :—						
Botryoidal, divergent, banded, compact............	37·438	10·20	99·40	1·095	0·17653	3·801
A similar specimen	49·265	11·60	99·80	1·430	0·17659	3·831

On some Rocks.

	W.	t_1.	t_2.	w.	Sp. h.	Sp. gr.
Granite; quartz felspar mica :—						
Fine-grained Aberdeen granite, contains a black mica and pink felspar..............................	31·253	10·98	99·85	0·998	0·18921	2·625
Coarse-grained, Ballyknockin (Co. Wexford), white felspar, silvery mica	42·105	13·50	99·70	1·312	0·19404	2·605
Medium grain, Killiney (Co. Dublin), white felspar, silvery mica..	41·200	13·34	99·40	1·2725	0·19269	2·645
Owing to the close agreement between the sp. heats of quartz and orthoclase (0·188), orthoclase granites will not probably vary much in sp. heat.						
Basalt :—						
Fine-grained, black (Giant's Causeway)	24·400	10·17	99·85	0·814	0·19961	2·883
Hornblende Diorite :—						
Coarse, fibrous, actinolite trap, dark green (Glendalough, Co. Wicklow)	40·265	12·25	99·90	1·409	0·21135	2·996
Slate :—						
Fine green slate (Bray Head, Co. Dublin)	32·874	10·54	99·90	1·133	0·20695	2·722

On three *Aerolites.*　Group—Sporadosiderites; sub-group—Oligosiderites; (Daubrée).

	W.	t_1.	t_2.	w.	Sp. h.	Sp. gr.
Fell at Adare, Co. Limerick, Sept. 10, 1813	67·095	12·52	100·18	1·9595	0·17875	3·604
,, Nanjemoy, Maryland, U.S.A., Feb. 10, 1825	38·865	12·25	100·18	1·1375	0·17854	3·601
,, Berlanguillas, Spain, July 8, 1811............	21·664	12·67	100·18	0·656	0·18566	3·435

The three are similar in appearance, rough, grey, with small grains of nickeliferous iron and magnetic pyrites. Analysis of the first (Apjohn): Iron and nickel = 23·07, magnetic pyrites = 4·38, chrome-iron = 3·34, earthy matrix = 68·47, alkalies and loss = 0·74.

Alphabetical List of the Specific Heats of some Minerals.

Temperature limits about 12° C. to 100° C.

	Sp. h.		Sp. h.
Aerolite, *a.*	0·1787	Hornblende, trap-rock, fibrous,	
„ *b.*	0·1785	green	0·2113
„ *c.*	0·1856	Hypersthene, massive, crystal-	
Albite, transparent crystals ...	0·1983	line	0·1790
Amphibole, black crystals	0·1963	Labradorite, grey, chatoyant.	0·1933
Apatite, translucent, green....	0·1829	Lepidolite, massive, crystal-	
„ opaque white-pink....	0·1920	line	0·2097
Aragonite, transparent crystals	0·2036	Leucite, crystals...........	0·1912
Barite, transparent crystals ...	0·1096	Limonite, crystalline, massive	0·2215
„ opaque lamellar	0·1117	„ fibrous, divergent..	0·2263
„ opaque, massive	0·1032	Malachite, botryoidal	0·1766
Basalt, fine black	0·1996	Microcline, cross hatched....	0·1915
Beryl, transparent crystals....	0·2066	„ fawn-coloured ...	0·1905
„ subtranslucent	0·2127	Muscovite, silvery	0·2049
Biotite, black	0·2057	Natrolite, translucent crystals	0·2375
Calcite, Iceland spar	0·2036	Oligoclase, subtransparent ..	0·2059
„ translucent rhombohe-		„ white, subtranslu-	
dron.............	0·2044	cent	0·1997
„ hexagonal prisms	0·2034	Orthoclase, transparent adu-	
„ „ „	0·2091	laria	0·1869
„ chalk...............	0·2040	„ subtranslucent,	
Chalcopyrite, bright, iridescent	0·1271	opaque	0·1890
Corundum, clouded..........	0·1981	Phrenite, botryoidal, green ..	0·2003
Cryolite, translucent	0·2548	Pyrites, cubes..............	0·1306
Epidote, crystals, dark green..	0·1877	Quartz, limpid	0·1881
Fluorite, transparent crystal ..	0·2118	„ transparent, hyalite..	0·2033
„ translucent	0·2126	„ white opal..........	0·2375
Galenite, crystals...........	0·0505	Serpentine, green...........	0·2529
„ crystalline	0·0492	Slate, fine green............	0·2069
„ „	0·0522	Sphalerite, well crystallised..	0·1144
Garnet, red crystals..........	0·1780	„ crystalline.......	0·1159
„ a red crystal........	0·1793	Stilbite, white radiating (dry)	0·2621
Granite, Aberdeen...........	0·1892	Talc, greenish-white soapstone	0·2168
„ Wexford	0·1940	Topaz, transparent, colourless	0·1997
„ Killiney	0·1927	Tourmaline, black crystals...	0·2004
Gypsum, rough, white	0·2737	„ brown crystals..	0·2111
„ acicular...........	0·2717	Vesuvianite, green crystals ..	0·1949
„ selenite	0·2721	Wernerite, opaque crystals ..	0·2003
Hematite, botryoidal, diver-		Witherite, translucent	0·1086
gent...................	0·1683		

III. " Note on a paper entitled ' On a New Form of Stereoscope ' ('Roy. Soc. Proc.,' vol. 40, p. 317)."   By A. STROH.   Communicated by Lord RAYLEIGH.   Received September 28, 1886.

Since the reading of my paper on " A New Form of Stereoscope " (' Roy. Soc. Proc.,' vol. 40, p. 317) my attention has been called to a paper read by Mr. Howard Grubb, F.R.A.S., at the Royal Dublin Society, 20th January, 1879.

I find that this paper describes the essential points of the apparatus, and I therefore desire to acknowledge the prior publication by Mr. Grubb.